IC 8842

Bureau of Mines Information Circular/1981

Preventing Large-Battery Explosions

By D. Cummins and S. F. Pangerl

UNITED STATES DEPARTMENT OF THE INTERIOR

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James G. Watt, Secretary
BUREAU OF MINES

This publication has been cataloged as follows:

Cummins, David

Preventing large-battery explosions.

(Information circular • Bureau of Mines ; 8842)
Bibliography: p. 11.
Supt. of Docs. no.: I 28.23:8842.

1. Electricity in mining—Safety measures. 2. Storage batteries—Safety measures. 3. Mine explosions. I. Pangerl, S. F., joint author. II. Title. III. Series: United States. Bureau of Mines. Information circular ; 8842.

~~TN295.U4~~ [TN343] 622s [622'.8] 80-606996

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PREVENTING LARGE-BATTERY EXPLOSIONS

by

D. Cummins[1] and S. F. Pangerl[2]

ABSTRACT

This Information Circular presents a brief history of the lead-acid battery and describes ways to prevent serious injury from battery explosions when servicing and charging lead-acid batteries, particularly in the surface mining industry. The Mining Safety and Health Administration (MSHA), U.S. Consumer Product Safety Commission, battery manufacturers, and the mining industry have all contributed information as well as recommendations for injury-free handling for this report.

INTRODUCTION

Mining industry employees are exposed to an increasing number of accidental explosions when hooking up lead-acid batteries (especially the larger sizes used on big equipment) for routine charging in the shop or temporary boosting in the field. These battery explosions, created by igniting ever-present hydrogen, often inflict acid burns to eyes and other parts of the body. An analysis of current MSHA and U.S. Consumer Product Safety Commission accident statistics indicates that workers are either not fully aware of the hazards associated with lead-acid batteries or become complacent.

This information circular is not intended to be a technical handbook. Instead it seeks to acquaint the reader with a variety of situations that can cause battery explosions and ways to prevent them. Data are summarized from handbooks, textbooks, and manufacturers' technical data sheets, together with the authors' personal observations in operating mines.

ACKNOWLEDGMENTS

MSHA and the Department of Consumer Protection helpfully provided statistics and advice on the basic study. The following representatives of private industry provided technical assistance: Jerry E. Berger, Support Manager,

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Health, Safety and Environment, Shell Oil Company, Houston, Texas; Ken Marshall, Vice President and General Manager, KW Battery Co., Skokie, Ill.; and J. L. Rooney and Chris Morris, Vice Presidents (Operations), Chloride Industrial Batteries, Kansas City, Kan.

The following mining sites were visited to discuss field experience: Washington Irrigation and Development Co. (WIDCO), Centralia, Wash.; Butte Operations, Berkely Pit, Anaconda Operations, Anaconda, Mont., Big Horn Mine, Sheridan, Wyo.; Morrison-Knudsen Co., Inc., Sarpy Creek Industrial Mining, Hardin, Mont.; and Decker Mine No. 1, Decker, Mont.

THE LEAD-ACID BATTERY

Background (5)[3]

The lead-acid storage battery has been used for over 100 years. During the 1920's, the battery replaced the magneto, carbide headlamps, and the hand-crank starter on cars and trucks. In recent years, several improvements have increased battery life and battery-charge capacity. Most improvements are confined to better methods of plate forming and reduction of impurities in the electrodes.

Today's batteries give optimum performance for several services. Stationary batteries generally use weaker acid for longer life. Portable batteries use stronger acid for larger charge capacity. Impurities in the sulfuric acid and in the battery plates significantly affect battery performance. Gassing (hydrogen production) can be caused by even traces of several impurities.

Hydrogen gas produced in the lead-acid battery is the primary source of battery explosions. Local action produces a small, continuous supply of hydrogen; however, the largest amount is generated during charging. This hydrogen production increases as the battery approaches full charge. Gradually reducing the charging current will minimize this tendency. As the lead ions plate out, excess current carries hydrogen ions instead of lead ions to the negative electrode.

Recent Developments

The maintenance-free battery uses a lead-calcium alloy instead of lead-antimony. The alloy aids in reducing hydrogen generation. Some maintenance-free batteries are sealed and do not need water during their normal life. One battery manufacturer states its maintenance-free battery produces less than 5 percent of the hydrogen produced by the standard lead-antimony battery.

Another new product is the spark-arresting ceramic vent, made with fine pores that prevent flames produced outside the battery from getting inside and causing an explosion. In a clean atmosphere, plugging of the vent is no problem. However, in a dusty atmosphere around most surface mines, plugging of

[3]Underlined numbers in parentheses refer to items in the bibliography at the end of this report.

these vents can cause pressure to build inside the battery and rupture the case. Thus, frequent cleaning may be required in the field.

"The Hydro-Catalator Corporation has developed a catalyst battery cap which converts hydrogen and oxygen to water. The caps have a dual function of preventing the escape of hydrogen from the cells and restraining the loss of water from the cells" (3).

These caps have not been tested in surface mining equipment. One battery source suggested these caps may not function properly in vehicles traveling over rough terrain where battery acid could be splashed onto the active element.

BATTERY CARE AND MAINTENANCE

Many battery problems are caused by improper care and maintenance, although most battery companies provide information on proper care. Good maintenance includes frequent cleaning to remove either metal dust or coal dust and any corrosion present. Metal dust can drain current from the battery. Coal dust having a high sulfur content is also corrosive. Under extreme dust conditions, the battery vent can plug, causing the case to rupture. Corrosive buildup between the cable clamp and terminal post increases electrical resistance, reducing the amount of deliverable power, and can drain current away from the battery. Several products are on the market for protecting battery terminals against corrosion. Corrosion on the battery clamps and terminal posts can be removed with a water solution of either washing powder or baking soda. Fizzing of the soda solution indicates the presence of acid. When all the acid has been neutralized, the fizzing will stop.

Tamping the cable clamps onto the posts with a hammer can do major damage. Also, using a screwdriver to pry the clamp off the post can separate the post from the lid. If the battery post is broken inside the battery, a resulting spark can cause an explosion. Special clamp pullers are available for removing cable clamps without damaging the bond between post and lid. When installing a fresh battery, always spread the clamps open before sliding them over the post. Then tighten the clamp for a good connection. This prevents rapid corrosion between post and clamp or the chance of spark during engine start.

If the battery is not firmly held in the battery box, bouncing from off-road service can damage the plates or the case. Actual location of the battery in the vehicle is important for several reasons. Workers have suffered back strain when removing batteries because of an awkward lifting angle. Acid may splash if the battery strap breaks or becomes loose during removal. Location also plays a major role in the ventilation of hydrogen gas that may accumulate in the storage box.

The liquid in the battery should be checked frequently and maintained at the proper level. A low liquid level provides space for a large accumulation of gas, which increases the intensity of an explosion. A low liquid level also may expose the plates, with the chance for sparks and a resulting

explosion. A high liquid level increases the chance of battery acid seeping out.

Never touch the two battery terminals with a pair of pliers or other metal objects to judge the charge by the size of the spark; if hydrogen is present in sufficient quantity, an explosion can result. It is also important to have the right polarity when connecting a dead battery to a charger. A battery charged with polarity reversed will have its life shortened and can be a hazard.

Jumping Batteries

Battery explosions on mining equipment can be reduced by using a safe procedure for jumping weak batteries; for example, a battery should never be jumped when the liquid is frozen. The rapid heating produced by jumping will cause expansion, possibly rupturing the case. The battery should be brought into a warm building and allowed to thaw slowly. Five conditions or acts can trigger explosions when batteries are jumped.

1. Sparking at the battery terminal when the last jumping cable is connected, or when the first cable is removed after engine start.

2. Connecting jumping cables with the wrong polarity. Wrong polarity may destroy the diode in the alternator and can explode the battery.

3. Connecting batteries of different voltages (that is, 12-volt to 24-volt).

4. Jumping a frozen battery.

5. A broken terminal post causing sparks inside the battery.

Three kinds of jumping cables may be used: slave cables, standard cables, and extra-long cables with a switch in the middle of one cable.

With the slave-cable setup, a plug-in connector is hard-wired to the side of the vehicle 2 to 4 feet from the battery. Some slave cables are held in one bundle and fixed to connect with only one polarity--positive (+) to positive (+), and negative (-) to negative (-). Two methods of achieving this are illustrated in figures 1 and 2. In figure 1, the terminals are offset about one-half inch. In figure 2, the terminals are mounted off center in a plug-in socket.

Standard jumping cables consist of two heavy-duty wires with alligator clips on both ends.

The third kind of cable is an extra-long standard cable with a switch in the middle of the black, or negative line.

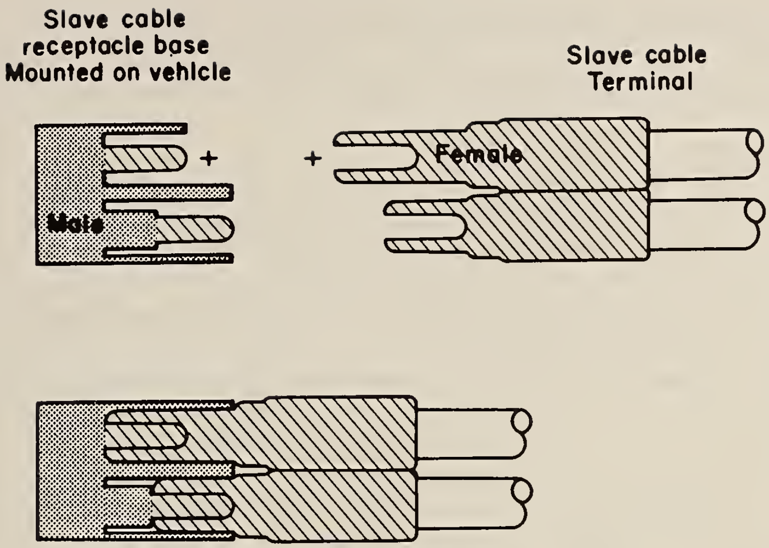

FIGURE 1. - Offset slave cable connector.

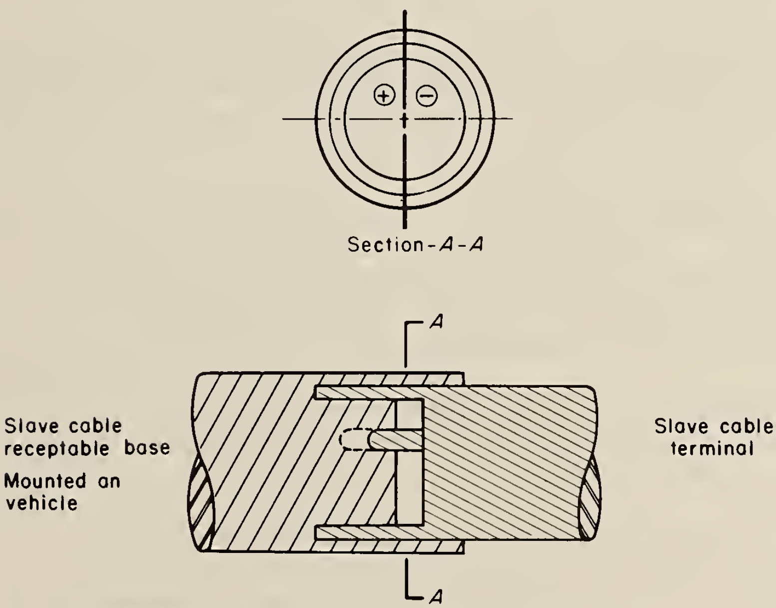

FIGURE 2. - Offcenter slave cable connector.

The fourth kind is called a "combination" cable. It is a jumping cable with a slave-cable connector put on one end and alligator clips on the other end.

With the slave cable setup, there is no risk of sparks near the battery, and the plug-in connector will only go together with the correct polarity. The lid on the battery box should be closed when the slave cables are being connected and when the engine is cranked. If the battery explodes, no acid will be splashed on the mechanic. This is a safe procedure.

With standard jumping cables, a strict jumping procedure must be followed. The generally recommended check procedure follows (1, 5):

1. Batteries must have same voltage.

2. Both negative posts grounded.

3. Check fluid level; check for freezing.

4. Vehicles not touching.

5. Ignition accessories off.

Only then ATTACH alligator clips in following order, and REMOVE in reverse order:

1. Attach one red clip to positive terminal on weak battery.

2. Attach the other red clip to positive terminal on good battery.

3. Attach black clip to negative terminal on good battery.

4. Attach other black clip to vehicle FRAME, a foot or more from weak battery.

In the surface mining industry, it is common to use both negative-ground and positive-ground equipment. Here, extra care should be taken to connect the batteries correctly. There are TWO critical rules to follow. ALWAYS connect like terminals--positive (+) to positive (+), and negative (-) to negative (-). ALWAYS make the last connection on the FRAME of the vehicle with the weak battery. ALSO, remove the cable connected to the FRAME first when disconnecting the jumper cables. Sparks will occur when completing an electrical circuit, and sparks will occur when breaking an electrical circuit. To avoid an explosion, keep all sparks a foot or more from the battery.

Additional safety may be achieved by placing a damp cloth or towel over the battery before attaching cables. A damp cloth can reduce the chance of a flame getting inside the battery to produce an explosion, and can prevent acid being splashed if an explosion does occur. In freezing weather, a dry cloth can be used.

When using extra-long cables with an in-line switch, the alligator clips should be attached--negative to negative--with the switch off. Next, connect positive to positive. The person can stand back about 8 feet, and turn on the switch to avoid splashing acid, should an explosion occur.

In case one battery has a slave-cable terminal and the other does not, use a "combination" jumping cable. The two alligator clips should be attached first. Then, the slave-cable connector should be plugged in. "Combination" cables are as safe as regular slave cables. However, it is necessary to attach the alligator clips with the correct polarity.

Slave cables provide a safe way to jump batteries. In most mines, slave-cable attachments are not installed on all vehicles, so an additional set of cables may have to be carried on the service vehicle.

The extra-long jumping cable with an in-line switch may be the least expensive, safest, and most versatile jumping cable. When the switch is turned off, this cable can be attached to both batteries in any sequence, and the only care that must be observed is connecting like polarities--positive to positive, and negative to negative. No problem develops when the two vehicles have opposite ground polarities--just connect positive to positive, and negative to negative. If the service truck has a 24-volt system consisting of two 12-volt batteries, a weak 12-volt battery can be jumped by attaching the alligator clips to one of the good 12-volt batteries.

When using standard jumping cables, there is less built-in safety, and extra caution is required, compared with that using slave cables or cables with an in-line switch.

If both vehicles have negative grounds, one list of safe jumping steps can be used. However, if both negative-ground and positive-ground vehicles are in use, then there are four possible combinations of safe jumping steps.

Field Service Examples

At one mine, a specially equipped truck services all disabled vehicles. Two heavy-duty, 12-volt batteries in the back of the truck are hard-wired to extra-long jumping cables with an in-line switch. Switches in the battery box permit these batteries to be charged from the truck's alternator, then disconnected. The jumping cables can be switched to one battery for 12 volts or to both batteries for 24 volts. With this switch setup, any vehicle can be serviced.

In another mine, a battery box with two heavy-duty, 12-volt batteries is mounted on a small trailer pulled by the service truck. A slave-cable connector is attached to the outside of the battery box. Three sets of jumping cables are used to fit any situation: slave cables, standard jumping cables, and a "combination" cable.

In cold weather, it was found that connecting to the weak battery and charging for 5 minutes improves starting. Current flowing through both batteries warms them and increases their available power.

DISCUSSION

Safety Considerations

1. All lead-acid batteries contain hydrogen gas above the liquid.

2. Hydrogen, in small amounts, is continuously generated in lead-acid batteries.

3. The primary production of hydrogen occurs during the charging cycle, especially as the battery approaches full charge.

4. To prevent excess hydrogen production, limit the charging current. A voltage regulator will reduce the charging current as the battery approaches full charge.

5. Maintenance-free batteries produce much less hydrogen than standard lead-antimony batteries.

6. Well-ventilated battery installations reduce the amount of explosive atmosphere in the battery vicinity.

7. When the only practical location for the battery is in the cab under the seat hydrogen gas is more likely to accumulate because of the poor ventilation. The maintenance-free battery would be of special interest here or in any location with poor ventilation.

8. A weak spark is sufficient to ignite hydrogen. The minimum energy to ignite hydrogen is about 10 percent of the energy needed to ignite methane (natural gas) (2).

9. Most battery explosions occur when a flame or spark is produced within a few inches of the battery. When the hydrogen gas ignites, the flame can feed back through the battery vent igniting the gas inside. Because the volume of gas is relatively small, the explosion is relatively small. The major hazard is from splashing battery acid, especially in the face and eyes.

10. In contrast to small inner-battery explosions where acid splash is the chief hazard, there is the possibility of an explosive blast in a confined area outside the battery, as illustrated in this unusual accident: hydrogen filled the vehicle cab, and the explosion knocked the mechanic down and blew the cab door several feet away. The battery under the seat was being charged, and the operator forgot to turn off the charger. The 8- to 10-hour overcharge created enough hydrogen to form the combustible mixture.

11. In addition to explosions, injury can occur from lifting heavy batteries. This is especially true with large equipment when the battery box is in an inconvenient location. This can be remedied by substituting three smaller 8-volt batteries for a 24-volt system.

Sources of Sparks or Flames

1. Attaching jumping cable to battery post or removing from the post.

2. Arcing across the battery post from--

   a. Dropping a metal tool across post accidentally.

   b. Using a metal tool to short battery to judge the amount of charge by the length of spark produced.

3. Using a match to check the liquid level in battery.

4. Smoking and allowing cigaret to pass close to battery vent.

5. Allowing cable clamp to remain loose around battery post.

6. Sparking caused by making or breaking an electrical circuit (shut off all accessories).

7. Static electricity developed from wearing synthetic fabric clothing in dry weather.

8. Sparks occur inside a battery:

   a. When a heavy current is drawn through a broken terminal post.

   b. When a short occurs between two plates with low liquid level.

CONCLUSIONS AND RECOMMENDATIONS

Most physical battery handling occurs in the battery shop. Here batteries are cleaned, tested, repaired, and charged--and accidents are minimal. Safety reports indicate most battery explosions occur when vehicles are serviced in the field and not by battery personnel in the shop. If everyone were as safety conscious about hydrogen escaping from batteries as they are about fumes escaping from gasoline fuel systems, most battery explosions would be prevented. All personnel handling batteries should have safety training, such as safety meetings and training films.

Battery accidents are more hazardous in the field than in the battery shop where gloves, aprons, and safety glasses are generally worn and safety showers are available for removing acid. In the field, there are no facilities for quickly washing off acid splash nor is there protection from rubbing eyes with acid on the hands.

Three types of cables (slave, "combination," and in-line with switch) place a person out of reach of danger when completing the final connection. To achieve comparable safety with a standarad jumping cable, cover the battery or wear protective clothing. Covering the battery with a damp cloth or towel is much simpler. In freezing weather, use a dry cloth.

Even when a list of safe jumping steps is followed, mistakes occasionally are made. Also, an explosion can occur if there is a broken post inside the battery. Never have your unprotected face over an uncovered battery when starting the engine.

The best recommendation is to use experienced personnel familiar with battery operation and service. However, when personnel with minimum experience are called upon to service batteries, certain safety steps must be followed. Slave cables, "combination" cables, or cables with an in-line switch will reduce chance of injury. But if standard jumping cables are used, all vehicles should have procedure decals at battery location or equally visible place stating:

1. Batteries must have same voltage.

2. Both negative posts grounded.

3. Check fluid level; check for freezing.

4. Vehicles not touching.

5. Ignition off, accessories off.

Only then ATTACH alligator clips in following order, and REMOVE in reverse order.

1. Attach one red clip to positive terminal on weak battery.

2. Attach other red clip to positive terminal on good battery.

3. Attach one black clip to negative terminal on good battery.

4. Attach other black clip to vehicle FRAME, a foot or more from weak battery.

When two vehicles have the same voltage, but different polarities, there are TWO must considerations: ALWAYS make the last connection, which produces the spark, on the frame away from the battery; and ALWAYS remove this connection to the frame first. ALWAYS connect terminals of like polarity--positive to positive, and negative to negative.

For added safety, place a damp cloth or towel over an uncovered battery before attaching cables. In freezing weather, a dry cloth can be used. Stand back before starting engine.

Make sure all accessories are turned off when installing a new battery or removing an old battery.

As an added precaution, the following safety tips should be observed:

1. Don't smoke or use matches around the battery.

2. Don't wear spark-producing synthetic fabrics near the battery.

3. Keep battery terminals washed free of corrosion.

4. Apply approved materials for corrosion protection to battery terminals.

5. Keep battery tied down snug in the battery box.

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☆U.S. GOVERNMENT PRINTING OFFICE: 1981-703-002/14

INT.-BU.OF MINES,PGH.,PA. 25216